

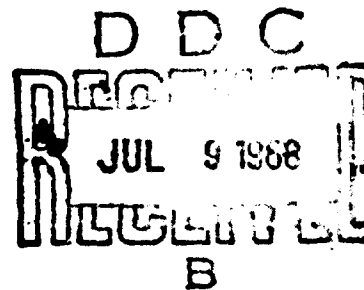
NAMI-1037

THE RELATIONSHIP OF THE NAVAL AVIATOR'S
SPEECH DISCRIMINATION TEST TO THE
PURE TONE AUDIOGRAM

James W. Greene



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April 1968

NAVAL AEROSPACE MEDICAL INSTITUTE
NAVAL AEROSPACE MEDICAL CENTER
PENSACOLA FLORIDA

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9 April 1968

NAVAL AEROSPACE MEDICAL INSTITUTE
NAVAL AEROSPACE MEDICAL CENTER
PENSACOLA, FLORIDA 32512

INTRODUCTION

The evaluation of the naval aviator's hearing in terms of his speech communication capability in the aircraft poses a special problem for the medical officer because only a pure tone threshold audiogram is required for the annual physical examination (1). Although the results of the pure tone threshold test may aid in detecting certain diseases of the ear and can successfully predict everyday speech capability, the question of the aviator's ability to understand speech in the aircraft usually remains unanswered. The standard clinical evaluations of speech reception show good correlation between the pure tone threshold levels at the speech frequencies and the speech test results for everyday speech adequacy. The average of the hearing threshold levels at 500, 1000, and 2000 Hz has been recommended (2) for evaluation of a person's ability to hear everyday speech. Kryter et al. (3) found that such an average tends to underestimate the importance of the frequencies above 2000 Hz and offered as a compromise an average of the hearing levels at 1000, 2000, and 3000 Hz for predicting speech capability. Neither of these methods, however, seems appropriate for evaluations of hearing ability of the aviator in his noisy environment, the aircraft.

At the present time, only those aviators whose hearing thresholds fail to meet the audiometric standards for Service Group III are given the opportunity to take the Naval Aviator's Speech Discrimination Test (NASDT) although some whose thresholds fell below Service Group I standards have also taken the test.

The following values are the maximum hearing levels in decibels for Service Groups I and III:

Hearing Standards for Aviators

		Frequency in Hz		
		500	1000	2000
Service Group I	Better ear	20	20	20
	Worse ear	20	40	40
Service Group III	Better ear	30	30	30
	Worse ear	-	-	-

The NASDT, formulated in 1964, involves listening to very loud speech embedded in a background of aircraft noise. It was developed to provide an objective basis for determining the future flight status of aviators whose audiograms fell below the standard for aviation. The acoustical levels for the speech and noise (115 db SPL and 100 db SPL, respectively) in the NASDT were set at approximately the same as those experienced in many naval aircraft so that all aviators, regardless of their degree of hearing loss, would receive the words well above their thresholds at any audiometric frequency.

A previous study (4) had indicated that there was no relationship between the NASDT score and the configuration of the pure tone audiogram; however, some doubt remained because only a limited number of subjects were available at the time the NASDT was validated. To further examine this lack of relationship, data from pure tone threshold tests and the NASDT scores were obtained for 61 senior aviators who were given the test after they failed to pass the hearing standards for aviation. The hearing tests and the NASDT were also given to over 500 men with different degrees of flight experience. This report presents a summary and statistical evaluation of these data which were obtained during the last five years.

PROCEDURE

The NASDT was administered to all subjects according to the established procedure (5). Audiometric data were obtained prior to each test by a Rudmose ARJ-4 or Maico H-1 audiometer. Descriptive statistics and Pearson product-moment correlations were computed for the six audiometric frequencies (right and left ears separately) and the NASDT scores. Certain groups of subjects classified largely upon the basis of flight experience were treated separately.

DESCRIPTION OF GROUPS OF SUBJECTS AND PRESENTATION OF DATA

The study group of primary interest was comprised of 61 senior aviators on active duty in the Navy, Marine Corps, and Coast Guard who were tested at different naval activities. Complete audiometric data for 23 individuals in this group were not available for the correlation studies, but their NASDT scores were combined with the remaining 38 scores to obtain an over-all mean value. Figure 1 shows the means and standard deviations for each audiometric frequency along with the mean value of the NASDT score for the 38 aviators with audiometric data.

The data obtained from this group have been analyzed further by separating those aviators whose audiograms definitely did not meet the standards for Service Group III from those whose audiograms fell between the standards for Service Groups I and III. Nineteen cases were found in each category. Figure 2 shows the data for those individuals who failed Service Group I standards and Figure 3 shows the data for Service Group III failures.

Some unpublished audiometric data and NASDT scores from men who are participants in the Pensacola "Thousand Aviator Study" (6) were available from records obtained during the 1963-1964 re-examination. Thirty of these former aviators had less than two years' flying experience, 90 had two to ten years' flying experience, and 163 had ten or more years' experience. Their average age was higher than that of our senior aviator group, but their audiometric data showed significantly less hearing loss, particularly at 2000 and 3000 Hz. These data are illustrated in Figures 4 to 6.

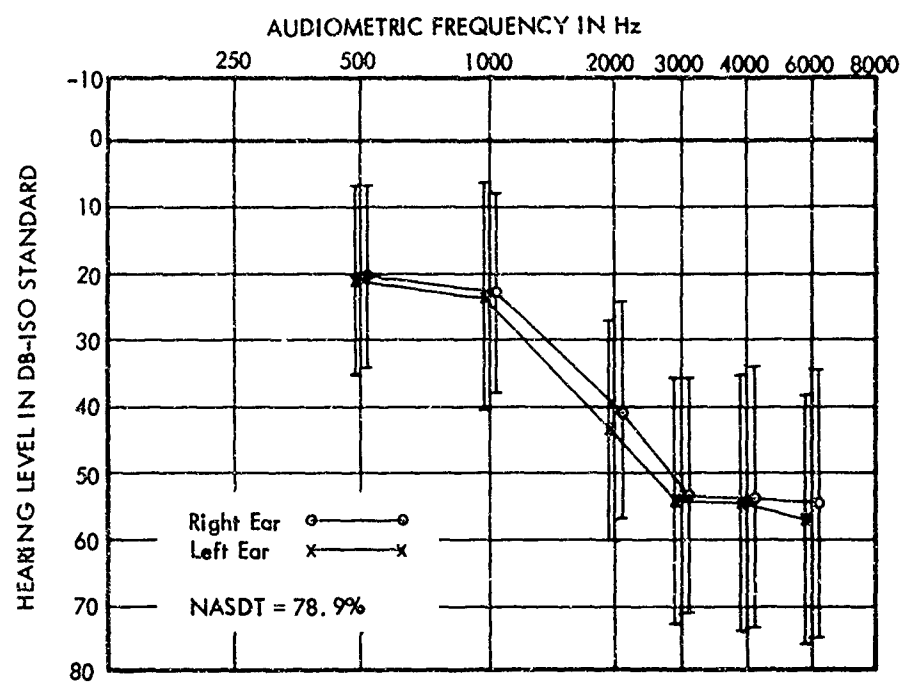


Figure 1

Audiometric Data and Mean NASDT Score
for 38 Senior Naval Aviators

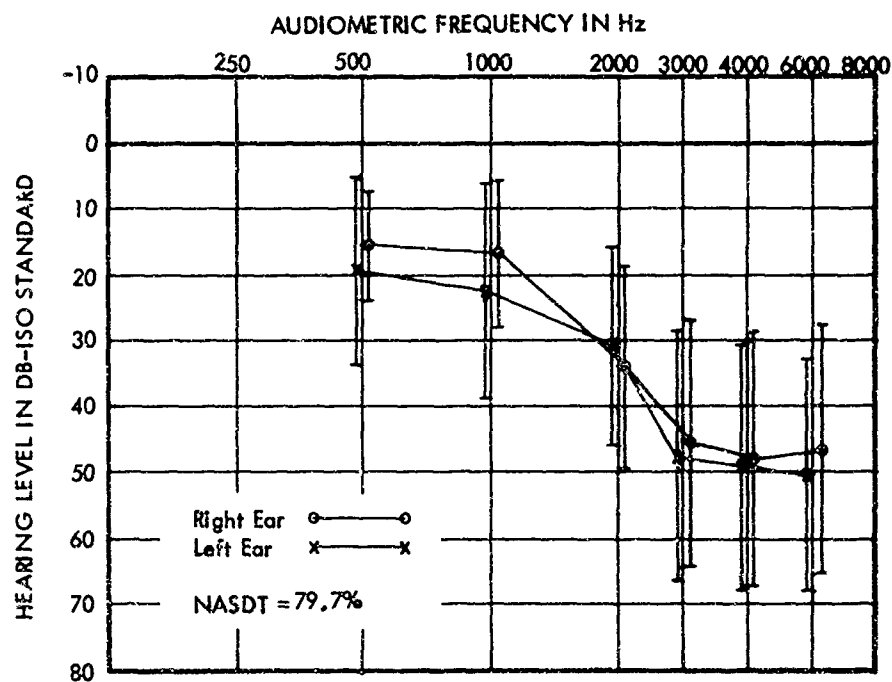


Figure 2

Audiometric Data and Mean NASDT Score
for 19 Naval Aviators below Service Group I Standards

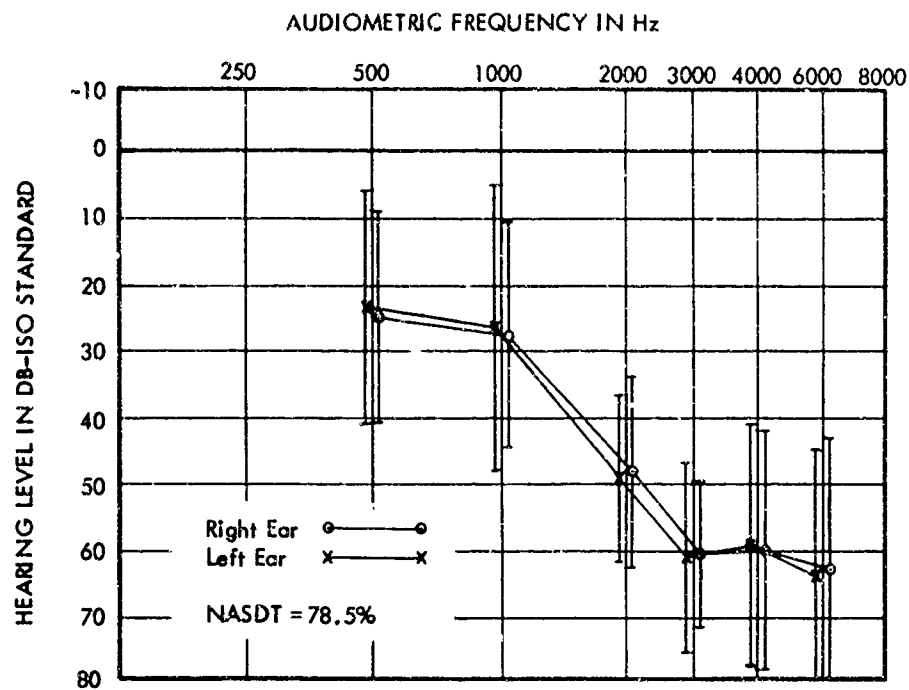


Figure 3

Audiometric Data and Mean NASDT Score
for 19 Naval Aviators below Service Group III Standards

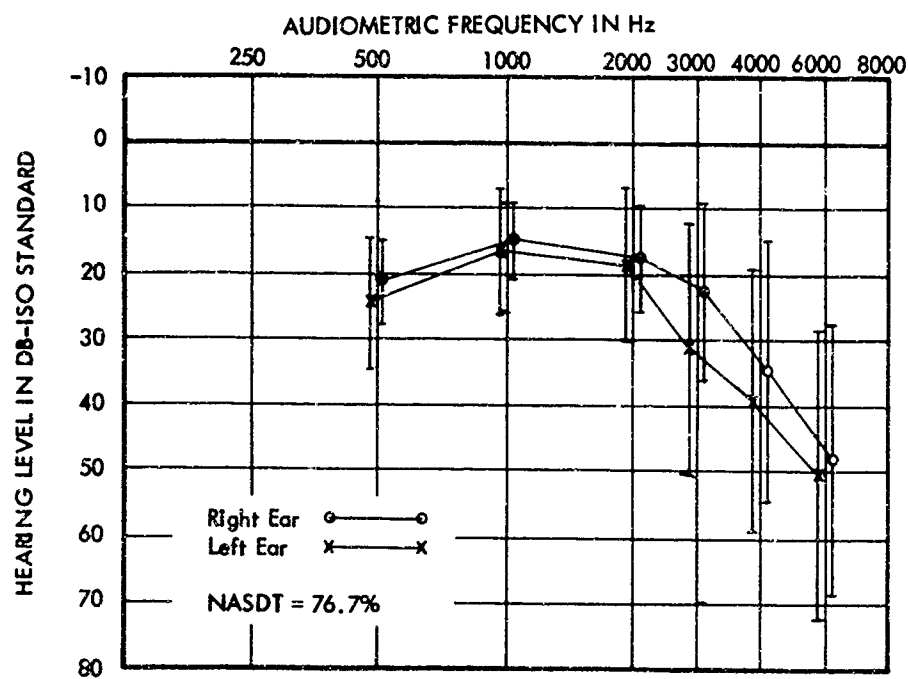


Figure 4

Audiometric Data and Mean NASDT Score
for 30 Naval Aviators with Less Than Two Years' Flying Experience

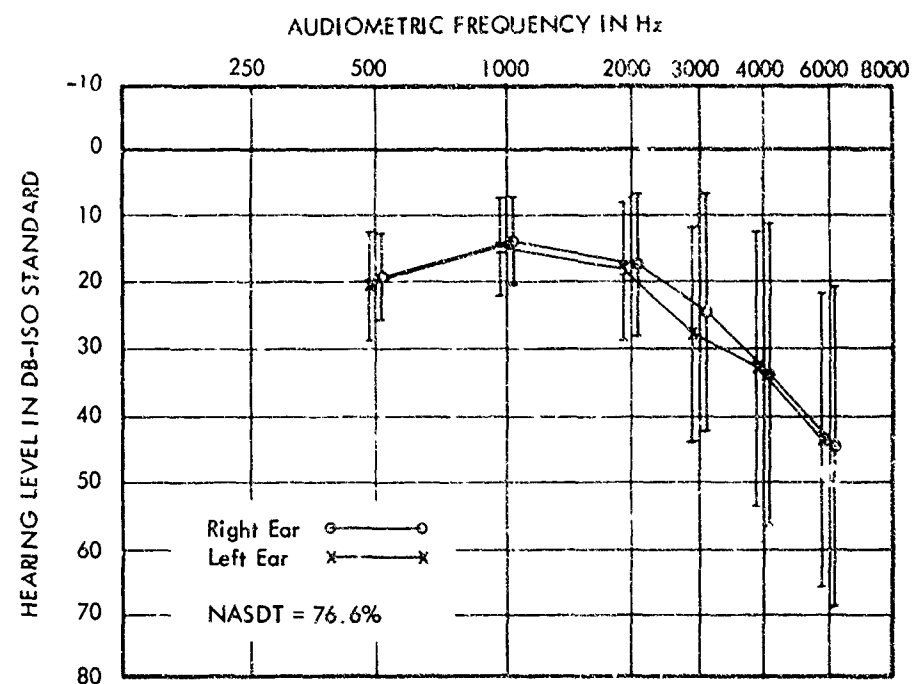


Figure 5

Audiometric Data and Mean NASDT Score
for 90 Naval Aviators with Two to Ten Years' Flying Experience

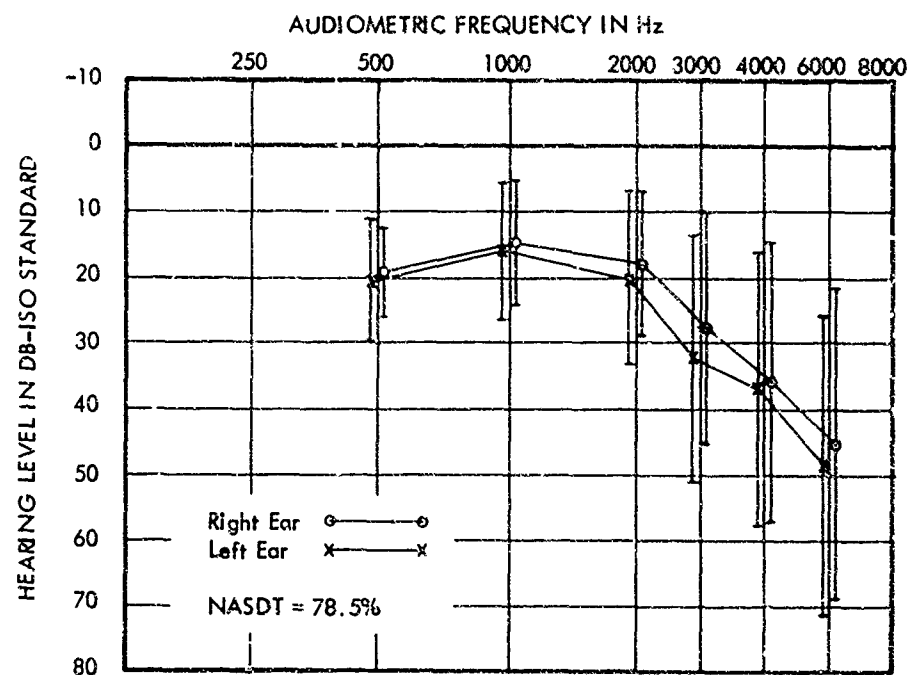


Figure 6

Audiometric Data and Mean NASDT Score
for 163 Naval Aviators with Over Ten Years' Flying Experience

The data for a group of 210 student aviators, who were given the NASDT prior to flight training during 1965 and 1966, appear in Figure 7. A composite of all groups for whom audiometric data were available is presented in Figure 8.

RESULTS AND DISCUSSION

The results of the testing procedures are summarized in Table 1 where mean hearing threshold data and a statistical description of the NASDT scores are arranged according to the different groups and subgroups. The mean hearing levels varied widely among the groups and were grossly related to age and flying experience. The senior aviators, however, had significantly greater hearing loss as compared to that of the "Thousand Aviator" group who had over ten years' flying experience. The mean hearing levels for this latter group can be considered normal for a sample with their age and flying experience. The senior aviators, on the other hand, had taken the NASDT as a result of having failed the pure tone threshold audiogram and thus represent that portion of a normal aviator population with greater than average hearing loss and, presumably, greater than average susceptibility to acoustic trauma.

The NASDT mean values ranged from 76.6 per cent to 79.7 per cent, with a grand mean of 77.8 per cent. This degree of consistency is surprising in view of the diversity of hearing threshold levels and flying experience among the different groups. It should be noted, however, that phonetically balanced word lists standardized for clinical use were used as test materials rather than sentences or aviation-oriented phrases. The problems of contextual cues and familiarity with aviation phraseology were avoided, and all subjects had an equal opportunity regardless of their age or flying experience.

When the standard deviation is subtracted from its respective mean NASDT score, a series of values from 69.8 per cent to 73.5 per cent is produced. These values fell in the vicinity of 70 per cent, which is the pass-fail cutoff score. The rate of failure varied from 5.0 per cent to 15.0 per cent, with an over-all rate of 9.7 per cent. The failure rate for the 61 senior aviator group was 9.8 per cent; but, it should be noted that, in case of failure on the first trial, the testing procedure provides that the aviator be allowed to repeat the test using an alternate word list. The scores used in this study were, of necessity, those which were reported in the health record and presumably included several second attempts.

It is not clear why certain individuals fail to obtain 70 per cent on the NASDT. Certainly, the audiometric data provide no clues, and there were no men in any of the groups with known handicaps. The masking noise used may distract certain individuals so that their performance is poorer, but distortion due to aural overload or tinnitus may also be contributing to lower NASDT scores. In order that an evaluation could be made of the relative significance of masking and distortion at high sound levels, a group of 100 additional flight students were given the NASDT words at 115 db SPL without the background noise. The test scores were much higher, with a mean of 94.5 per cent

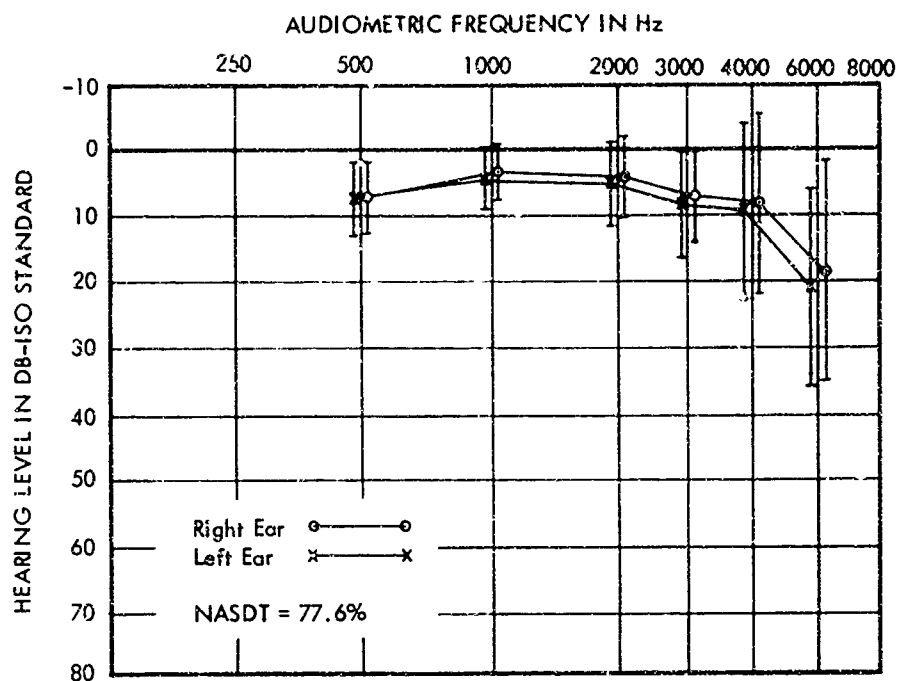


Figure 7

Audiometric Data and Mean NASDT Score
for 210 Student Aviators

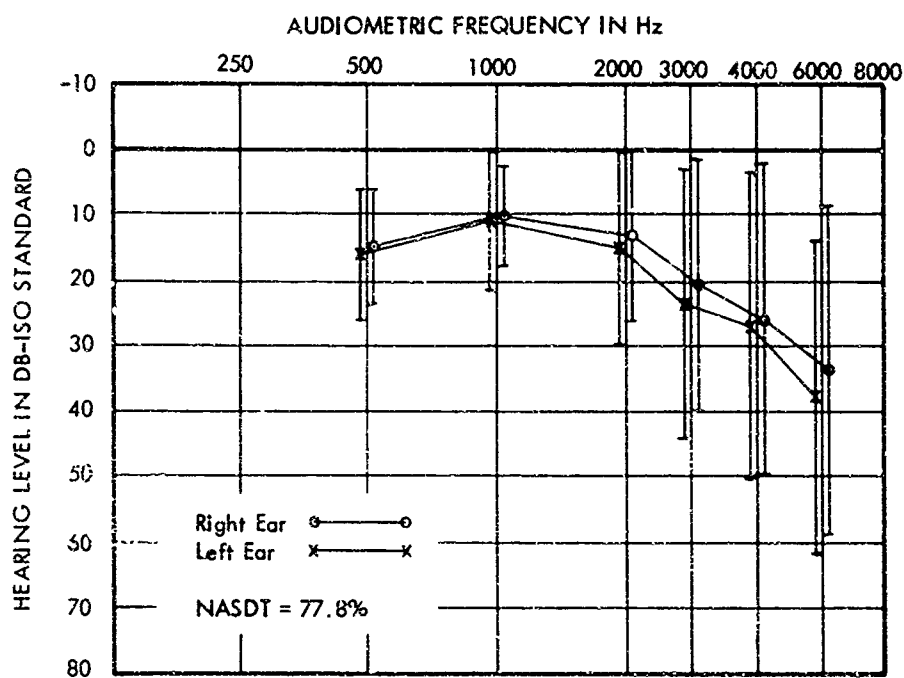


Figure 8

Audiometric Data and Mean NASDT Score
for Overall Group of 531

Table 1
Mean Hearing Levels and Statistical Description of NASDT Scores for Different Aviator Groups

Group	N	Ear	Mean Hearing Levels in Decibels						NASDT Statistical Description						Failure Rate %	Average Age Years	Average Flight Time Hours
			Audiometric Frequency (Hz)-ISO Standards						Mean %	S. D. %	Range %	%	%				
			500	1000	2000	3000	4000	6000									
Senior aviators	61	-	-	-	-	-	-	-	78.3	6.95	58 to 91	9.8	42.8	5234			
Senior aviators Below SG I	19	R	14.8	15.8	34.8	45.3	46.5	46.0	79.7	6.22	65 to 90	5.0	40.8	4824			
		L	18.2	21.8	31.4	47.1	47.8	50.2									
Senior aviators Below SG III	19	R	25.1	28.2	47.4	59.8	60.1	62.5	78.5	7.62	63 to 91	15.0	44.8	5612			
		L	23.5	27.1	48.8	60.3	60.1	64.8									
Naval aviators Less than 2 yrs Flying experience	30	R	21.1	14.6	16.8	22.7	33.8	47.3	76.7	6.18	66 to 89	13.3	47.0	117			
		L	24.0	16.5	18.8	31.5	39.5	51.0									
Naval aviators 2 to 10 yrs Flying experience	90	R	19.2	13.9	17.1	24.5	33.4	44.8	76.6	6.76	45 to 88	13.3	46.3	3516			
		L	20.5	14.6	17.7	27.5	32.7	43.8									
Naval aviators Over 10 yrs Flying experience	163	R	19.1	14.9	17.8	27.7	35.9	44.9	78.5	5.68	62 to 91	6.7	46.9	6299			
		L	20.5	15.6	20.3	32.4	36.8	47.7									
Student aviators	210	R	8.2	3.5	3.8	7.2	8.9	18.9	77.6	5.91	61 to 90	10.0	22.2	0			
		L	8.5	4.1	5.3	8.3	9.6	21.1									
Overall	531	R	15.0	10.7	13.8	20.5	25.9	34.4	77.8	6.14	45 to 91	9.7	-	-			
		L	16.0	11.6	15.3	23.5	26.7	37.4									

and a standard deviation of 2.4 per cent. Clearly, then, for subjects with normal hearing, a mean score on the NASDT of 77.8 per cent is almost completely due to the masking noise. For subjects with various degrees of sensori-neural hearing loss, however, we should expect that aural distortion may cause the variations in speech discrimination at high levels.

To visualize the masking effect better, a spectrum analysis of the speech and noise used in the NASDT was performed and is presented in the Appendix. The average vowel energy below 630 Hz has a better signal-to-noise ratio than the consonant sounds of speech above 1000 Hz. The noise masks those frequency components which have a level similar to the noise background and results in confusions for certain speech sounds. The words containing these sounds are missed more frequently than others. Conversely, many words are not affected by the noise and could be deleted without sacrificing the quality of the test.

A matrix showing the correlation coefficients between the hearing thresholds at each audiometric frequency and the NASDT scores is presented for the total sample in Table II. Adjacent frequency pairs for each ear and pairs for both ears at each frequency have high correlations, while all other frequency pairs have correlations generally below .707. The correlations between the hearing threshold levels and NASDT scores, however, are not significantly different from zero. The hearing levels and NASDT scores, therefore, share virtually no common variance, and hence the predictive ability of the individual pure tone threshold levels for the NASDT score is nil. The intercorrelations among hearing levels within the different subgroups do not present any clear pattern, but the correlation coefficients between hearing levels and NASDT scores generally are insignificant.

Combinations of frequencies are used as predictors of hearing ability for everyday speech. In the method described by the American Academy of Ophthalmology & Otolaryngology (2) the average of threshold levels at 500, 1000, and 2000 Hz is computed for each ear separately. The values can then be used to determine the binaural hearing impairment in percentage. For this study, however, the simple average was correlated with the NASDT scores for 38 senior aviators for whom hearing data were available. The correlation coefficients for an N of 38 were $-.33$ for the right ear and $.04$ for the left ear. With the method of prediction proposed by Kryter et al. (3) a simple average of the threshold levels at 1000, 2000, and 3000 Hz is used. This method when applied to the same group of 38 men produced correlation coefficients of $-.37$ and $-.02$ for the right and left ears, respectively. The practical implication of these findings is that the hearing threshold levels or recommended combinations thereof cannot successfully predict performance on the NASDT.

Table II

Pearson Product-Moment Correlations between Hearing Levels and NASDT Scores for 531 Aviators

	500 R	1000 R	2000 R	3000 R	4000 R	6000 R	500 L	1000 L	2000 L	3000 L	4000 L	6000 L	NASDT
500 R		.803	.571	.493	.487	.489	.616	.558	.465	.453	.454	.465	.003
1000 R			.726	.604	.543	.489	.526	.645	.573	.514	.467	.415	-.050
2000 R				.810	.659	.541	.383	.495	.732	.647	.557	.477	-.046
3000 R					.832	.685	.315	.422	.672	.786	.701	.576	-.093
4000 R						.804	.304	.381	.568	.728	.786	.662	-.096
6000 R							.301	.360	.461	.612	.712	.740	-.064
500 L								.820	.546	.481	.443	.403	.062
1000 L									.676	.562	.510	.446	.030
2000 L										.782	.656	.554	-.048
3000 L											.860	.704	-.051
4000 L												.822	-.046
6000 L													-.037
NASDT													

CONCLUSION

A considerable amount of data has accrued during several years' use of the NASDT. Mean scores for the various groups taking the test have varied consistently around 78 per cent. The apparent diversity of the groups in terms of age, flying experience, and hearing levels should not overshadow the fact that all the men underwent a thorough physical examination prior to entrance into flight training. Therefore, a generalization of the findings to nonflying personnel would not be in order.

The NASDT appears to provide a more realistic evaluation of the communication capability of the aviator in the noisy environment of his aircraft than does the pure tone threshold audiogram. The virtual lack of correlation between the NASDT scores and the audiometric thresholds indicates that the two tests are measuring completely different aspects of hearing. It should be emphasized, however, that the NASDT is not to be substituted for the pure tone threshold audiogram but should supplement it in the hearing requirements for all aviators.

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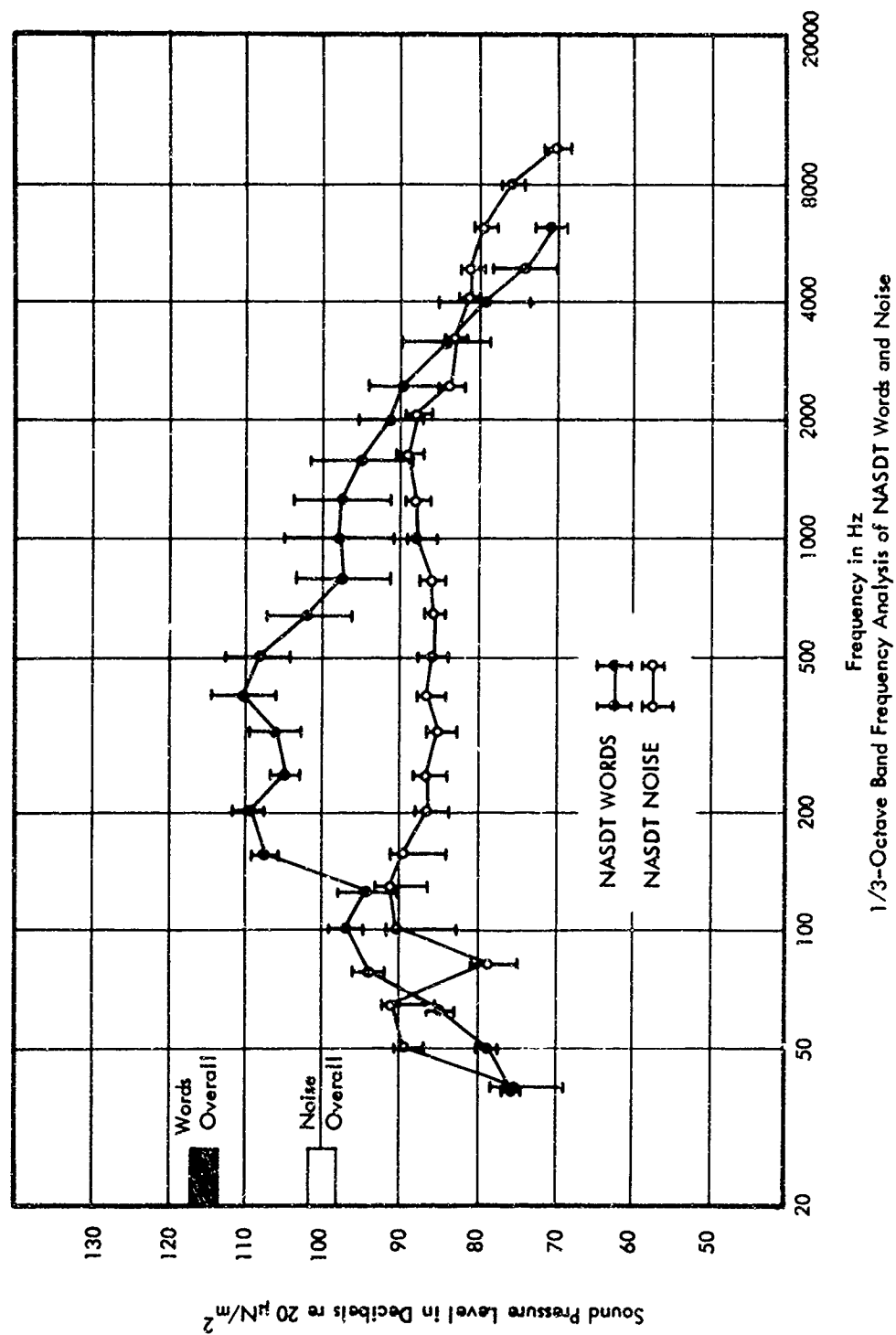
APPENDIX

Spectrum Analysis of NASDT Words and Noise

Each word in List 1A2A of the NASDT was recorded on a magnetic tape loop system and scanned with a 1/3-octave band frequency analyzer. The output of the analyzer was written out on a high-speed level recorder, and the amplitude values of the tracings were compiled according to each frequency band. The means and standard deviations were computed for each band and plotted on adjacent graphs.

The background noise frequency analysis was obtained in a similar manner. The values, however, represent the average noise levels with variations above and below those levels due to the character of the C-45 aircraft noise.

The over-all frequency response of this system from the disc reproduction to the tape loop scanning is 50 to 10,000 Hz \pm 2 db. Most of this relatively minor variation occurs at the ends of the frequency range.



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KEY WORDS		ROLE	WT	ROLE	WT	ROLE	WT
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Speech discrimination							
Speech intelligibility in high-intensity noise							
Hearing loss							